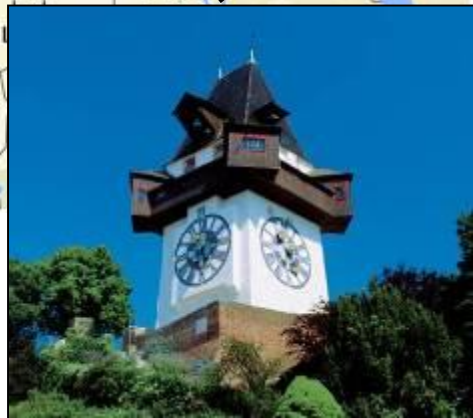
BCI standards

Christoph Guger
g.tec, Austria, Spain, USA


MOZART


Musical
Empress
Elisabeth


Emperor‘s castle



Northwestern Passages
Kalaallit Nunaat Greenland
Hudson Bay
North Atlantic Ocean
Gulf of Mexico
Caribbean Sea
Cuba
Puerto Rico
Guatemala
Nicaragua
States
Sweden
Norge
Norway
United Kingdom
Ireland
Éire
Deutschland
Germany
Polska
Poland
Беларусь
Belarus
Україна
Ukraine
France
România
Romania
Italia
Italy
España
Spain
Portugal
Ελλάς
Greece
Türkiye
Turkey
Tunisia
المغرب
Morocco
الجزائر
Algeria
الصحراء الغربية
Western Sahara
Mali
Niger
Burkina
العراق
Iraq
ایران
Iran

Research Projects

H2020 SME project: recoveriX - motor recovery after stroke

H2020 SME project: ComaWare – coma assessment and communication

H2020 Eurostars project: ComAlert – coma prediction

H2020 Eurostars project: RapidsMaps – high gamma mapping

EC project: Neurographene – development of Graphene electrodes

EC project: ReNaChip - Rehabilitation of a discrete sensory motor learning function

EC project: Sm4all – Smart Home for all

EC project: RGS – Rehabilitation Gaming System faster recovery from stroke

EC project: BrainAble - BCI with VR and social networks

EC project: Decoder - BCI for locked in patients

EC project: CSI - Central Nervous System Imaging

EC project: BETTER BCI for Stroke rehabilitation and rehabilitation robots

EC project: VERE – Virtual Embodiment Real Embodiment

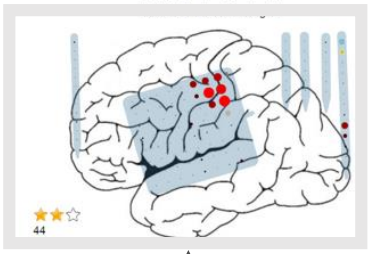
EC project: ALIAS – Adaptable Ambient Living Assistant

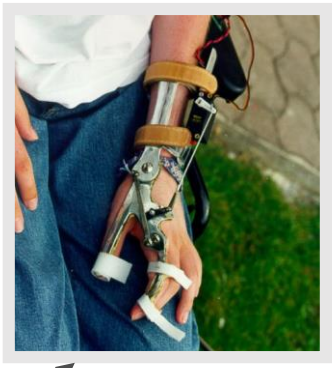
EC project: BACKHOME – BCIs for end users

EC project: DENECOR

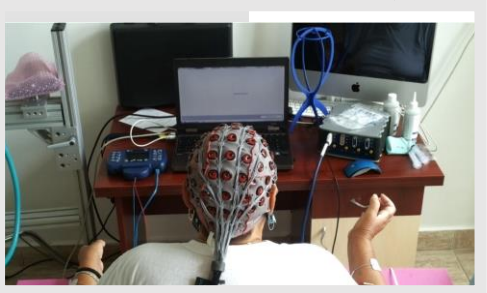
EC project: High Profile

Current g.tec BCI applications





BCI



Changes of brain electrical activity and mental strategies

- Slow cortical potentials (anticipation tasks)

  DC-derivation, artifact problem, difficult strategy, feedback method

- Steady-State Evoked potentials (SSVEP, SSSEP)

  Flickering light with specific frequency

- Event-related, non-phase-locked changes of oscillatory activity ERD/ERS (motor imagery tasks)

  Changes of mu-rhythm, alpha activity and beta activity over sensorimotor areas; imagination of hand- ,foot-, tongue- movements

- Evoked potentials (focus on attention task)

  Thalamic gating, various methods of stimulation (visual, tactile, electrical, auditory, ...), P300

- Code based evoked potentials (focus on a code)

Problem 1: Different sensors

Non-invasive versus invasive (different regulations, FDA, CE)

Depth electrodes, grids versus EEG electrodes

Active or passive electrodes

Gel or dry EEG electrodes

Different number of channels (P300: 8, SSVEP: 8, motor imagery: 64, invasive mapping: 256)

Different sampling frequency (Spikes: 40 kHz, ECoG: 1-4 kHz, EEG: 256 Hz)

Different platforms (Windows, Linux, Android,…)

Ⓐ g.MOBIlab+
- ☐ EEG version
- ☐ multi-purpose version

☐ g.GAMMAcap

☐ Consumables

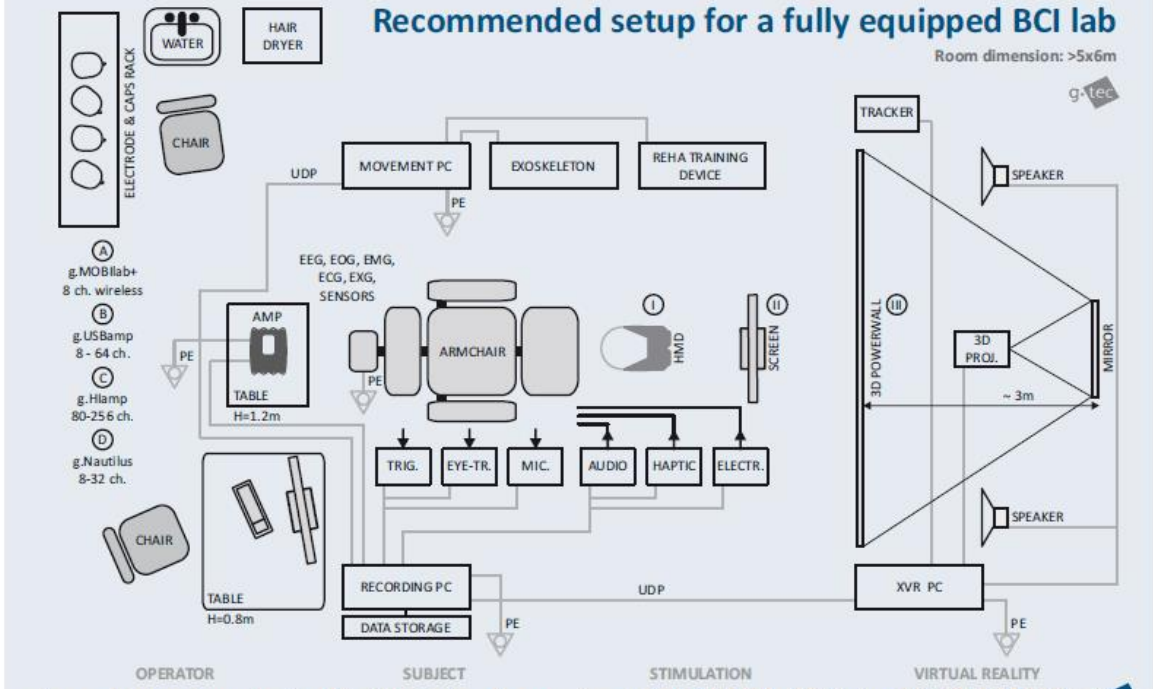
Electrodes
- ☐ active
- ☐ passive
- ☐ dry

Ⓑ g.USBamp
- ☐ 16 channels
- ☐ 32 channels
- ☐ 48 channels
- ☐ 64 channels

Ⓒ g.Hlamp
- ☐ 80 channels
- ☐ 144 channels
- ☐ 256 channels

Ⓓ g.Nautilus
- ☐ active-gel
- ☐ active-dry
- ☐ 8 channels
- ☐ 16 channels
- ☐ 32 channels

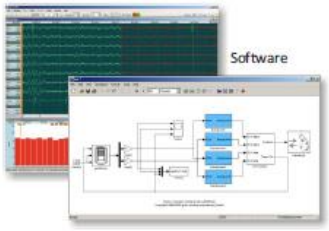
Recommended setup for a fully equipped BCI lab



g.tec medical engineering GmbH, office@gtec.at, www.gtec.at, tel. +43 7251 22240, fax +43 7251 22240 39

☐ Impedance tester
☐ Signal generator

☐ VR-system



Software

- ☐ g.Recorder
- ☐ g.BSanalyze
- ☐ g.Hlsys (Simulink)
- ☐ g.Hlsys (LabVIEW)
- ☐ intendiX
- ☐ BCI2000
- ☐ C/MATLAB/Linux API
- ☐ g.RTanalyze
- ☐ g.PHYSIOobserver
- ☐ g.UDPinterface
- ☐ mindBEAGLE
- ☐ cortiQ
- ☐ Eyetracker interface
- ☐ g.NEEDaccess

Examples
- ☐ P300
- ☐ Motor imagery
- ☐ SSVEP
- ☐ CSP/RehaBCI
- ☐ Vibro-tactile P300
- ☐ Ping-Pong game
- ☐ Hyperscanning
- ☐ Hybrid BCI
- ☐ EMG/EOG control

Training material
- ☐ EEG lecture
- ☐ EP lecture
- ☐ BCI lecture

☐ Eyetracker (screen-mounted)
☐ Eyetracker (head-mounted)

Sensors
- ☐ GSR
- ☐ Blood pressure
- ☐ Respiration
- ☐ Temperature
- ☐ Pulse
- ☐ Acceleration
- ☐ More sensors

☐ Electrical stimulator

☐ g.STIMbox
☐ g.SSVEPbox

Request an offer for a complete lab
☐ minimum ☐ basic ☐ advanced

Check products of interest and request an offer per fax (+43 7251 22240 39) or e-mail (office@gtec.at) !

How do interface with different amplifiers

g.NEEDaccess service to interface all amplifiers with one common interface

A. C++ Application Program Interface (API)

- integrate amplifiers into own software under Windows and Linux

B. MATLAB API

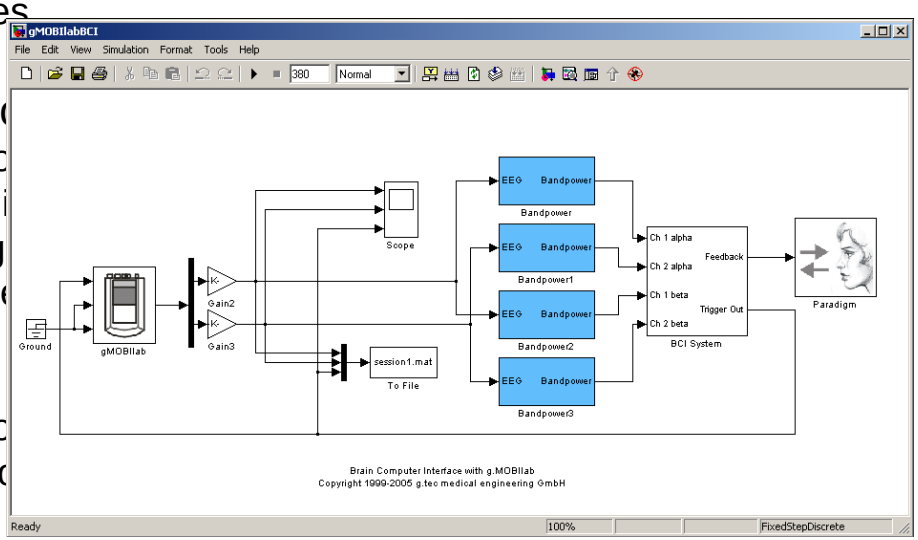
- integrate amplifiers into MATLAB data acquisition and analysis programs
- access all toolboxes (Signal Processing, Neural Networks,…)
- access user written M-files

C. Simulink Highspeed on-line Pr

- amplifier device driver blc
- copy the block into Simuli (S-functions) and paradig
- just exchange the amplifie processing blocks

D. LabView

- amplifier device driver blc
- use standard LabView blc



All three options give full access to hardware

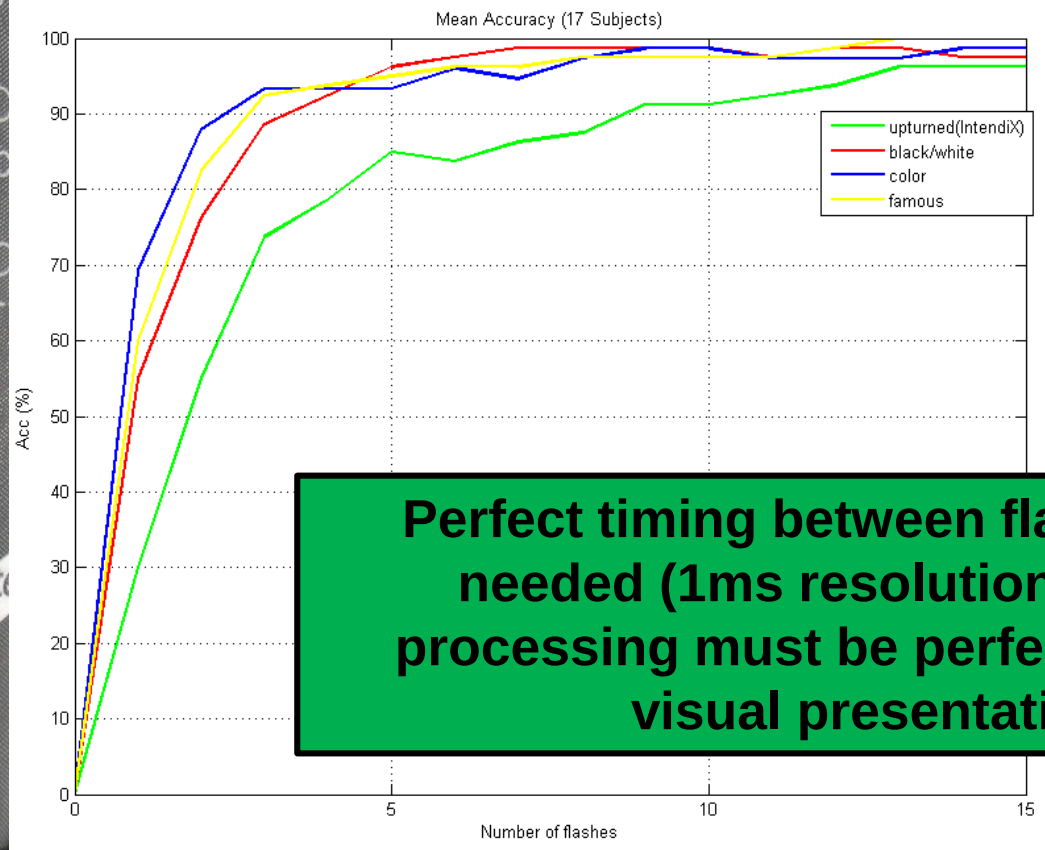
- bandpass, notch settings
- sampling frequency
- impedance check
- synchronization with digital inputs
- direct integration of other devices

Problem 2: Event Timing

Real-time data stream synced with external devices
- visual P300: 1 ms resolution
- vibro-tactile P300: 1 ms resolution
- ….

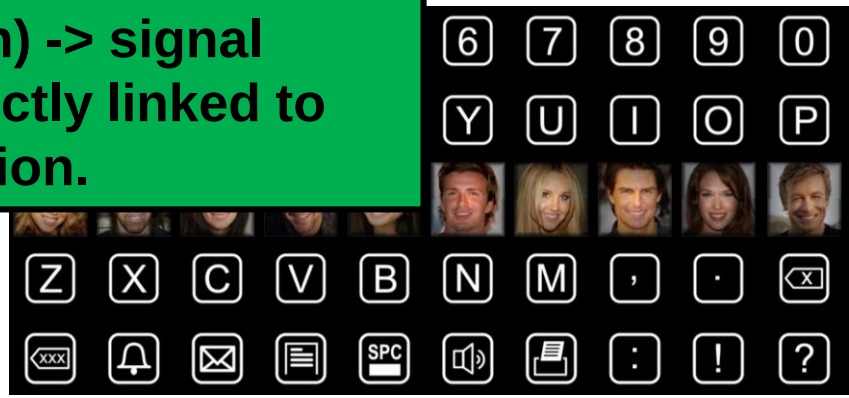
Control of external devices
- UDP
- digital outputs

intendiX – face speller



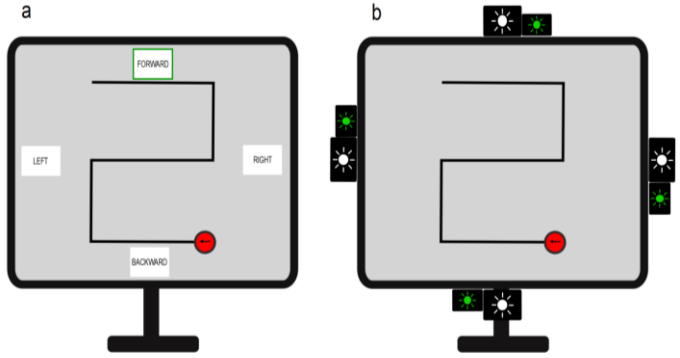
- 17 subjects
- 4 tasks
  - Standard flashing
  - „Einstein“ (black/white)
  - „Einstein“ (color)
  - Face speller

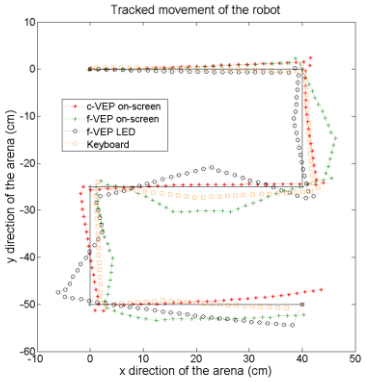
Perfect timing between flash and EEG needed (1ms resolution) -> signal processing must be perfectly linked to visual presentation.



Everybody achieved 100 % accuracy

BCI interface with video overlay





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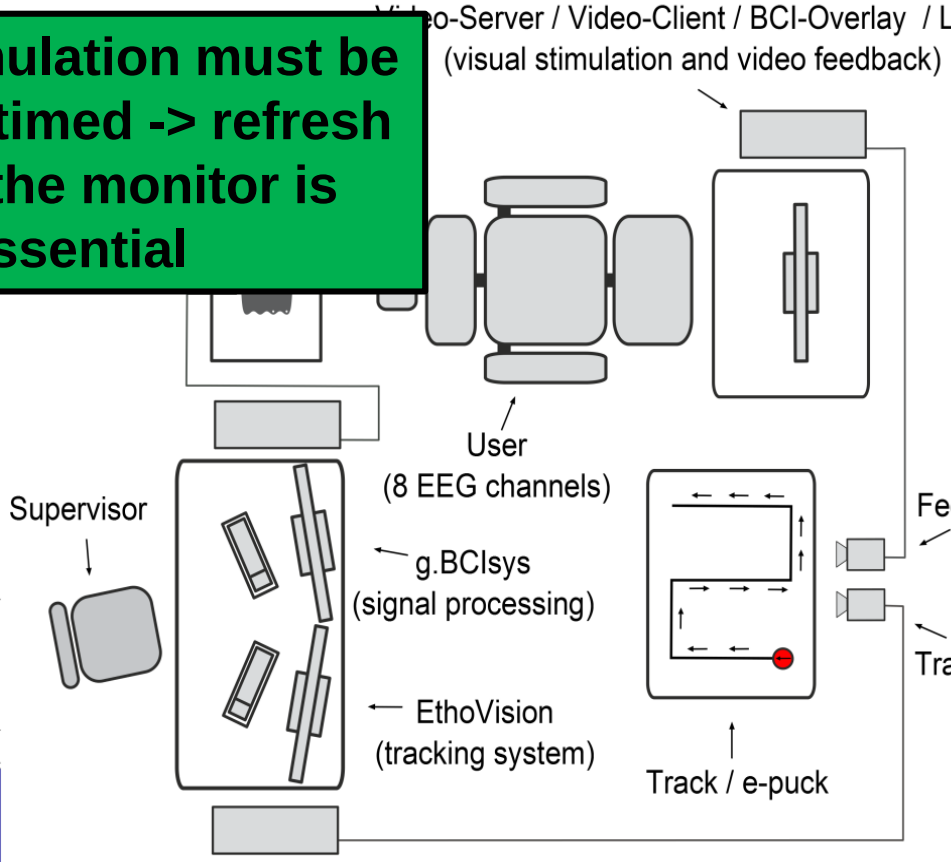
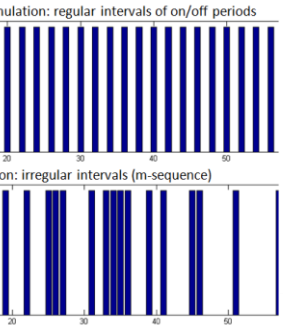
Code stimulation must be perfectly timed -> refresh rate of the monitor is essential





11 subjects participated

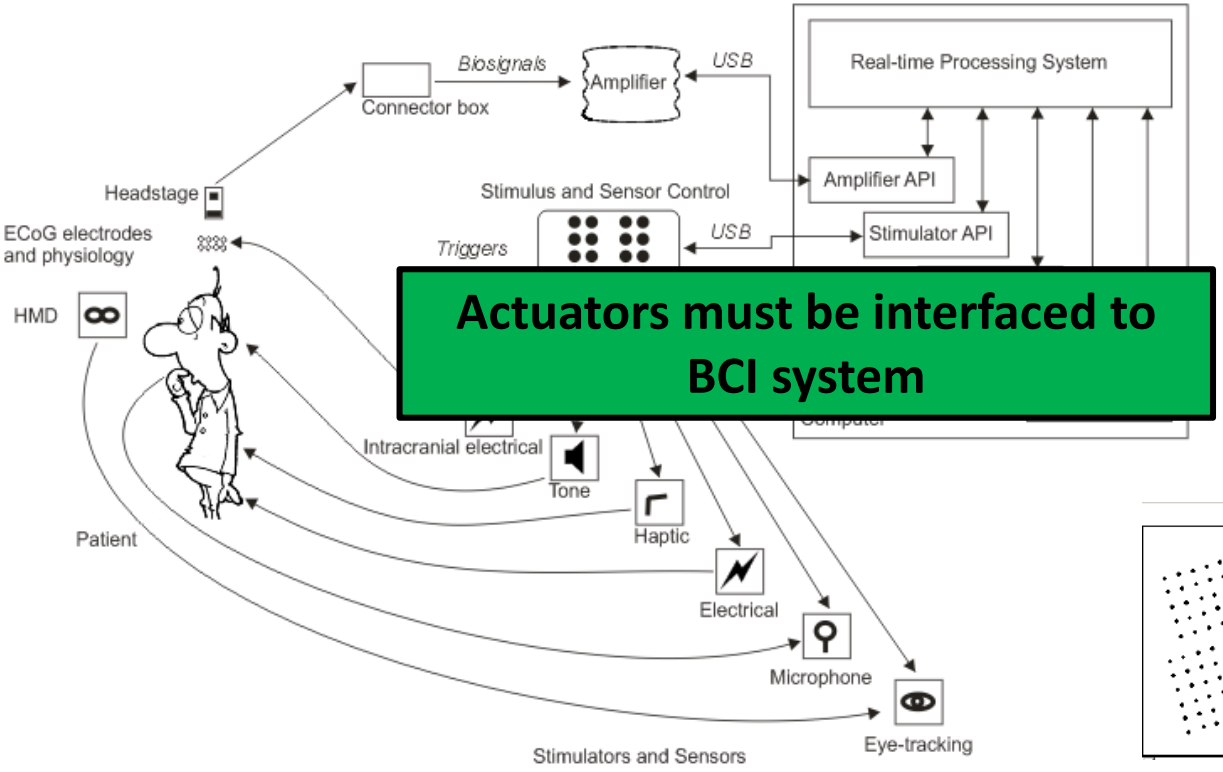
LED stimulation: 91,36 %
Screen stimulation: 91,36 %
Code based screen: 98.18 %.

Average time to complete the tasks
222.57 s (code based BCI),
437.43 s (frequency LED)
573.43 s (frequency screen).

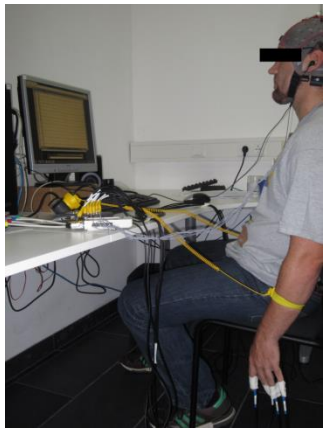
Submitted to Frontiers, 2013

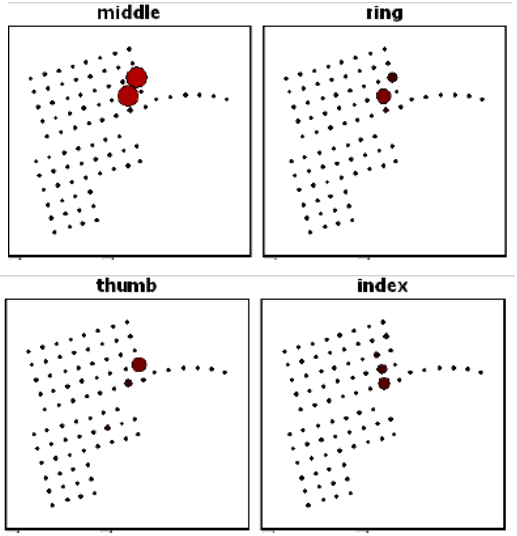
Robot control in VERE video

Embodiment Station



Actuators must be interfaced to BCI system





Gerwin Schalk, Wadsworth Center

Stimulate the body and observe effects in the brain -
-> real-time functional mapping

Stimulate the brain and observe effects on the body
-> real-time sensing

Aim: Build a functional cortical atlas.

cortiQ - Clinical software for electrocorticographic real-time functional mapping of the eloquent cortex.
Prueckl R, Kapeller C, Potes C, Korostenskaja M, Schalk G, Lee KH, Guger C.
Conf Proc IEEE Eng Med Biol Soc. 2013 Jul;2013:6365-8. doi: 10.1109/EMBC.2013.6611010.

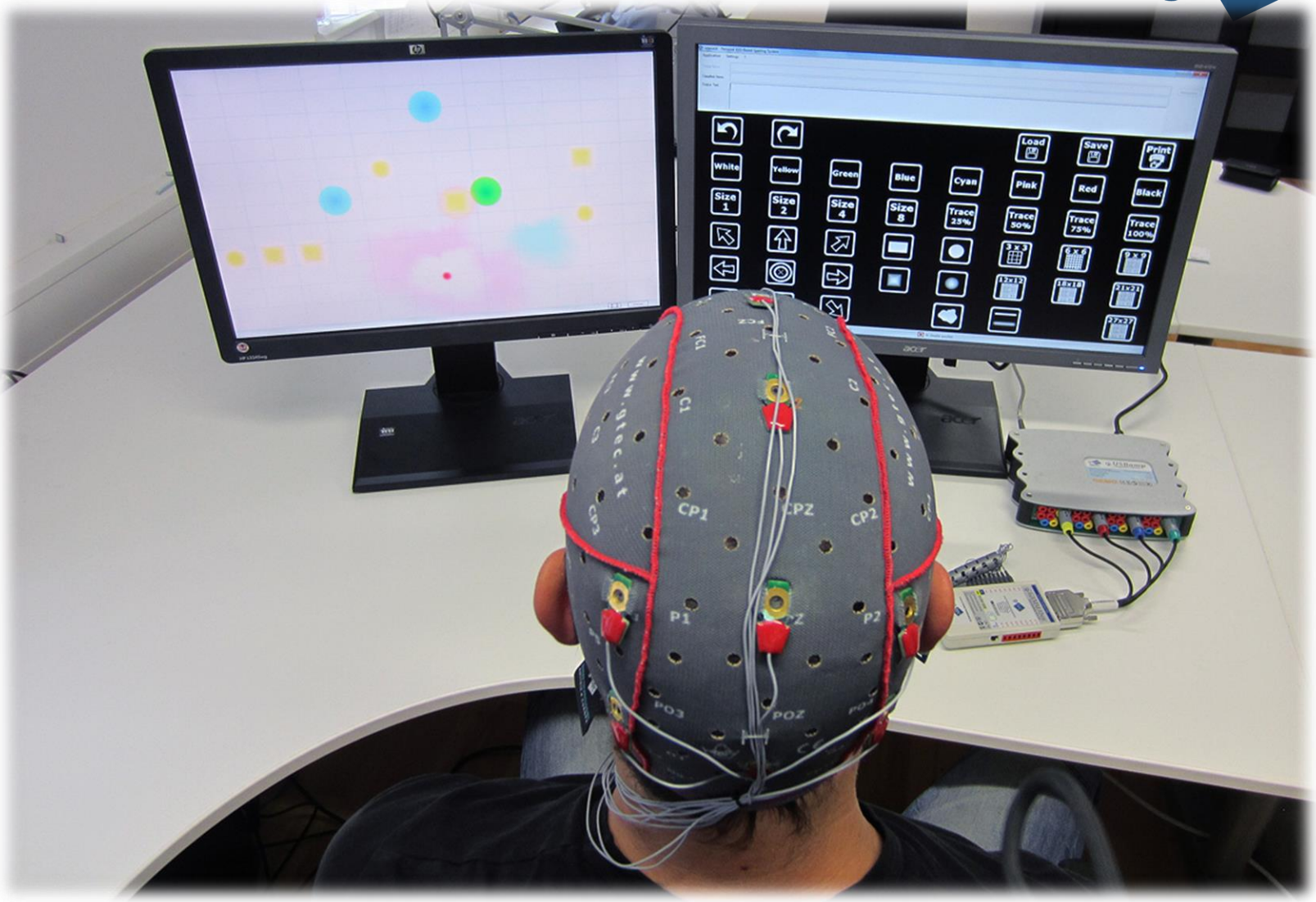
Problem 3:
Many controllable elements

Smart home needs many controls for domotic devices

BCI has to understand which controls are necessary

BCI must be updated to changes of the environment

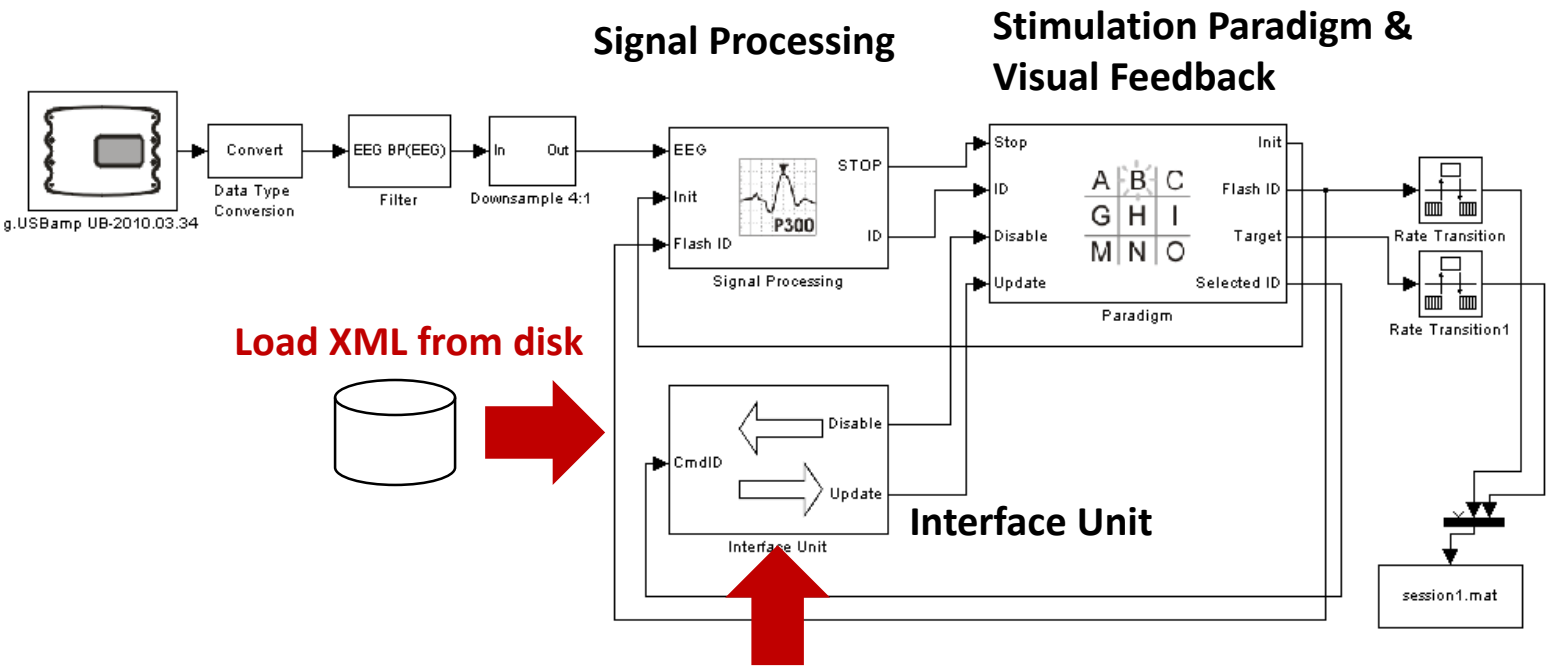
Brain Painting Application



Designed by Adi Hösle

ACTOR protocol

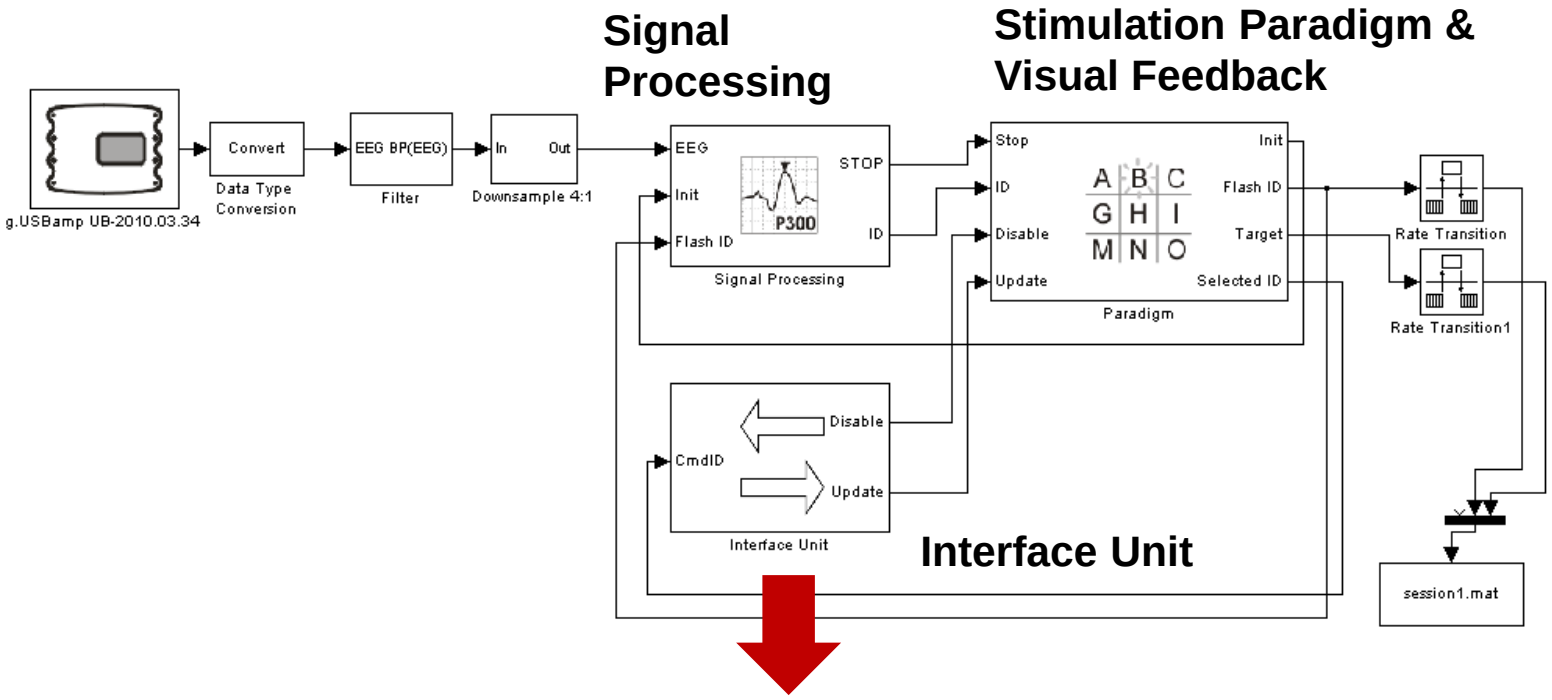
- The BCI speaks with ACTOR protocol with the avatars and robotic systems
- **XML files** are loaded **at startup** (from disk or from a text string, which is received over the network)
- **Updates** of the XML files can be received at runtime over UDP: **Modify the contents of the BCI at runtime**, e.g. to achieve context awareness



C. Hintermüller, C. Kapeller, G. Edlinger, C. Guger (2013): "BCI Integration: Application Interfaces" Book Article in "Brain-Computer Interface Systems – Recent Progress and Future Prospects" R 44879, Intec, book chapter

The XML based BCI Standard

- Each **interaction** (e.g. the letter ‘A’) is related to an instruction string
- If ‘A’ is selected: the **string is sent over UDP**:
  A **remote device or applications can be controlled with the BCI** just by knowing an IP address and the instruction string



Send instruction ‘A’ to a remote device or application (e.g. Twitter)

The Virtual Reality Apartment

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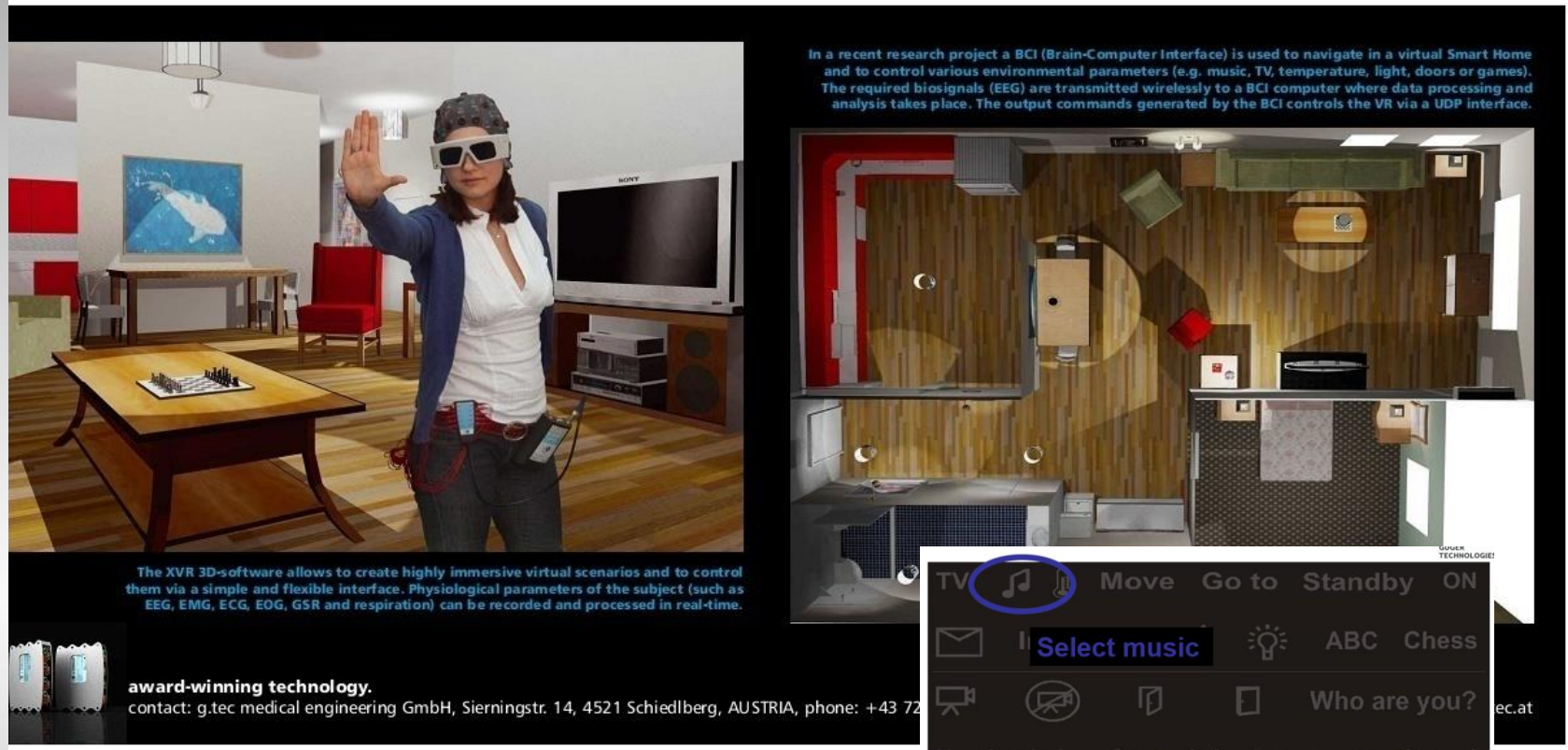

Designed by Chris Groenegress, Mel Slater

Problem 4: Avatar/robot control

The person is seeing the environment through the avatar or robotic system

We need BCI controls for controlling the avatar/robot

The BCI system has to send control command to external system

Interfacing with rehabilitation devices

Screen overlay control interface - SOCI

Video: Overlay BCI

World of Warcraft

4 controls:

Turn left, right, move forward, perform action like grasping objects, attacking other objects

60 Hz LCD display with 15, 12, 10 and 8.75 Hz.

BCI overlay based on OpenGL –

can be used with any graphics application

[Video]

Humanoid Robots for Physical Embodiment

[BCI control to grasp a Coke]() [EuroNews]() [DigInfo]()

Abderrahmane Kheddar, CNRS

Problem 5: Highly immersive feedback

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Stroke rehabilitation with BCI system

recoveriX
MOTOR-RECOVERY NEUROTECHNOLOGY

Motor imagery BCI controls FES and avatar

BCI accuracy is objective parameter for training

Motor recovery controlled with 9-hole PEG test

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Problem 6: Performance standards

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BCI performance comparison

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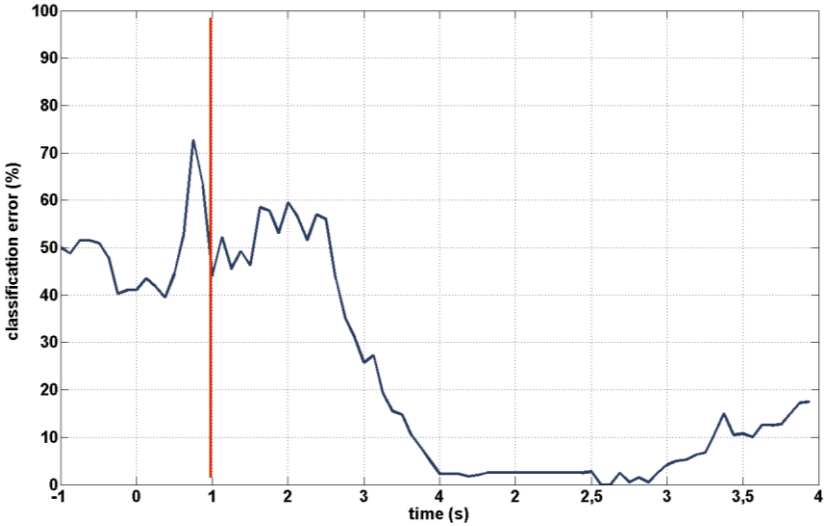
Important that some systems are not called BCI systems

	Motor imagery	cVEP	P300 speller [Guger 2016]
Grand average accuracy	87 %	98 %	100 %
Training time	30 min	5 min	5 min
Number of electrodes	32	8	8
Random classification accuracy	½	¼	1/36
Decision time for selection	6 sec	3 sec	About 45 sec with 15 flashes
Location	Motor cortex	Visual cortex	Central line and visual cortex

Hand Movement Task

- **Movement: Online classification accuracy (video)**
- **Imagination: Online classification accuracy (video)**

BCI-ECoG setup



Classification accuracy

Problem 7: Calibration

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SSVEP group study accuracy

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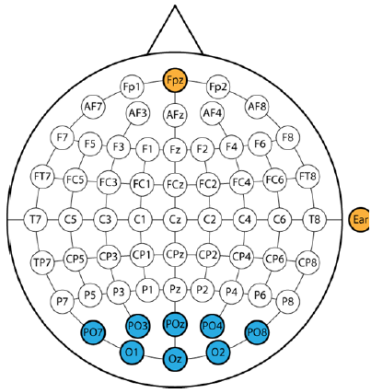
Accuracy (%)	Number of subjects performing at specified accuracy				Percentage of people after training
	Run 1	Run 2	Run 3	Run 4	
100	22	25	27	27	50.9
90-99	14	19			
80-89	7	4			
70-79	2	1			
60-69	1	2	1	1	1.9
50-59	4	1	0	0	0.0
40-49	3	0	1	0	0.0
0-39	0	1	0	0	0.0
Mean Accuracy	87.9	92.9	95.0	95.5	
	N=53	N=53 with 14 new	N=53 with 7 new	N=53 with 2 new	

BCIs need calibration phase to achieve high performance



Poor performance in SSVEP BCIs: Are worse subjects just slower?

frontiers IN NEUROPROSTHETICS

How many people could use an SSVEP BCI?, Christoph Guger, Brendan Z Allison, Bernhard Grosswindhager, Robert Prückl, Christoph Hintermüller, Christoph, Kapeller, Markus Bruckner, Gunther Krausz and Guenter Edlinger, Frontiers in Neuroprosthetics, 2012.

Problem 8:
Good looking BCI users

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